Time Components File for Space VLBI

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1 Introduction

The Time Corrections File, or "DeltaT File," is intended for use at a correlator to correct the times written into the tape headers for errors in the timing reference received at the spacecraft ([1]). The corrections are computed at the end of each tracking pass from various measurements made in real time [2]. Various mission elements, particularly correlation facilities, may need to make use of additional details about the information included in the DeltaT File, especially components that may show a variety of time-dependent signatures. In addition, for accountability of measurements, assumptions, and models, the component corrections are needed in order to maintain a long-term record of the treatment of the Space VLBI data. The "Time Components File" defined in this specification would serve these purposes. It is intended that the present specification of the Time Components File be read in conjunction with the specification of the Time Corrections File [1]; this document has borrowed extensively from the text of that specification.

The format of the Time Components File makes use of the Flexible Image Transport System (FITS), which was originally developed for storing astronomical images [3] and has now been adopted as a NASA standard which is maintained by the NASA Office of Science and Technology [4]. Each DeltaT File would have a corresponding Time Components File covering the identical time range, and having a name allowing it to be uniquely associated with the appropriate DeltaT File. Although each Time Components File would cover exactly the same time range as the corresponding DeltaT File, the reporting interval for the components may be a multiple of the reporting interval used in the Time Corrections File.

2 Logical Content of the File

Each component time correction value in the file represents a correction that has already been incorporated in the DELTA_T Table of the Time Corrections File. Often, this will be the earth station's best estimate of the time that has been *added* to the time written on the wideband data tape ("tape time") for a given effect, but this is not required. The actual meaning of each type of correction will be specified in separate documents written by those responsible for each earth station. Each correction is labeled with the station UTC at which the corresponding two-way timing link signal was received on the ground, and it applies to the data sample that was received at the same time. Note that these component corrections have already been included in the DELTA_T Table and need not be applied again.

Further details of the calculations involved in creating the DELTA_T Table are given in [2]. For the Green Bank station, a separate document describes in detail all effects for which corrections are applied, along with the methods used to determine them [5]. A preliminary description (now somewhat outdated) of the corrections made in data supplied from the JPL-DSN tracking stations was given in [6], and more details on the tracking station implementation are given in [7].

3 File Format

3.1 Overall Description

The file shall be a FITS Table File [3]. Such a file consists of header "keywords" describing the contents of the file; table "keywords" describing each individual table; and binary data tables, which are multi-dimensional arrays of numbers.

Table 1: Required Header Keywords for Time Component File

Keyword	Interpretation
DATE-OBS	Date of the earliest data in this file. (Eight character string date "dd/mm/yy" UTC)
DATE-MAP	Date when this file was created. (Eight character string date "dd/mm/yy" UTC)
VERSION	File version number. This entry and DATE-MAP are provided in case errors are discovered in the file after it has been transmitted, so that a corrected version needs to be generated; or in case new information allows a more accurate version to be generated. (This is a number string representing an integer, initially zero, and incremented each time a new version is generated.)
TELESCOP	Spacecraft identification. At this time, three identifiers are defined: "VSOP_SC", "RA_SC" or "SU_SC".
OBSERVER	Earth station identification. At this time, the following identifiers are defined: "TDBIN_TS", "GOLDS_TS", "PUSHN_TS", "GBANK_TS", "USSUR_TS", "EVPAT_TS", "MADRD_TS" or "USUDA_TS".

3.1.1 File Header Keywords

These keywords describe the origin and contents of the file. A set of FITS keywords is required to indicate that the file is a valid FITS file; these are not described here (see [4]). Other header keywords, listed in Table 1, are optional to generic FITS file readers but are required for Time Component Files. Note that these file keywords are separate from the table keywords described in Section 3.2.

3.2 Time Component Tables

Each file shall include one or more tables containing the time components data. A separate table must be generated for the data following each clock setting event. (See also discussion in Section 3.4, below.) The format of each table shall conform to the registered FITS extension called "BINTABLE" [4].

3.2.1 Time Component Table Keywords

Each Time Component Table shall include at least the keywords given in Table 2. Additional keywords are required either by basic FITS or by the BINTABLE extension; these shall also be included, but are not described here.

3.2.2 Columns of Component Values

At each time step (1/REP_RATE), the Time Component Table contains m values, one for each of the m effects being included for a particular earth station. The total number of columns in the table, and hence the total number of values at a given time, is not fixed, and may be different for different earth stations. The contents of the nth column will be governed by the keyword TTYPEn; the exact meaning of TTYPEn will be defined separately in documents to be written by each earth station's operators. Several somewhat generic values of TTYPEn have already been defined, based on commitments by earth-station operators to supply certain types of data in the Time Component Table; see Section 3.2.5.

Table 2: Required Keywords for Time Component Table

Keyword	Interpretation
EXTNAME	The string "T_COMP", indicating the type of table.
EXTVER	Integer enumerating the order of tables in this file. The first "T_COMP" table will have EXTVER=1 and the value will be incremented for each successive table, in order of increasing time.
REP_RATE	Reporting rate of the time component values in this table, in Hz. The value should be an integer submultiple of the sampling rate (SAMPRATE) used in the corresponding DELTA_T table.
DATE	Modified Julian Day number (MJD) of GND_TIME, TAPETIME, and UTC_DATA, below.
GND_TIME	UTC of the clock setting event, in seconds.
TAPETIME	Time label on the tape of the clock setting event, in seconds. This will normally be an integer, and therefore might correspond to the time in an actual tape header, but this is not guaranteed.
UTC_DATA	UTC of the first time correction value this table, in seconds. This time must be *earlier* than the clock setting event given by GND_TIME. All succeeding values in the table occur at intervals of 1/REP_RATE. Note that there are no time tags internal to the table.
TTYPEn	Name of the nth column of the table ($\leq$ 8 alphanumeric characters):
TUNITn	Units of the nth column of the table. Typically, this will be "SECONDS".
TFORMn	Data type of nth column: "1D", which denotes one IEEE double precision number.

3.2.3 Invalid Values

If error conditions are detected at the earth station which imply that some component values may be invalid, then each such value shall be replaced by a special bit pattern, namely 0xFFF0000000000000. This pattern is the IEEE code for "$-\infty$", and therefore it could not be a valid value.

3.2.4 REP_RATE

The standard repetition rate (REP_RATE) shall be an integer submultiple of the sampling rate (SAMPRATE) in the corresponding DELTA_T Table. For example, for a 10.0 Hz SAMPRATE, REP_RATE may take on values such as 10.0 Hz, 5.0 Hz, 2.0 Hz, 1.0 Hz, 0.5 Hz, or 0.25 Hz. Typically, a REP_RATE near 1.0 Hz may be expected.

3.2.5 Keywords TTYPEn for Column Definitions

Three keywords that may be used for TTYPEn have been defined generically. Those keywords are (1) TROPCOMP, (2) IONOCOMP, and (3) CLOCKCOM. The values in columns associated with these TTYPEn keywords will represent respective corrections that have been made for (1) the non-reciprocal part of the Earth's troposphere; (2) the non-reciprocal part of the Earth's ionosphere; and (3) the variation in the station's clock reference relative to true UTC. Other corrections may be represented by additional columns with other TTYPEn keywords. The precise definitions of the effects and of the keywords for each individual earth station are the responsibility of the earth station's operators, and shall be documented separately.

3.3 Time Labels

The time label of the first value in each Time Components Table is specified in the table header by the DATE and UTC_DATA keywords. Thereafter, the time labels of all values in the table are at intervals of exactly 1/REP_RATE. These times will not generally occur on evenly-quantized boundaries of UTC, even if the raw data on which they are based were sampled on such boundaries. This is because UTC_DATA includes the effect of the fixed delay in the station hardware between arrival of the signal from the spacecraft and obtaining a value of the timing residual.

3.4 New Tables

A New Time Components Table shall be written to correspond to each new DeltaT Table in the Time Corrections File.

4 Availability

The Time Components File will be available to authorized users within 24 hours of the end of a tracking pass in accordance with the procedures in [8, 9].

References

[1] L. D'Addario and G. Langston. Time corrections file interface. Specification A34300N004F, November 1996.

[2] L. D'Addario. Post-pass processing of the two way timing measurements. OVLBI-ES Memo 38, February 4, 1993.

[3] D. C. Wells, E. W. Greisen, and R. H. Harten. FITS: a flexible image transport system. *Astronomy and Astrophysics Supplement Series*, 44:363–370, 1981.

[4] NASA Office of Standards Technology (NOST). Definition of the flexible image transport system (FITS). Technical Report 100-1.0, NASA Goddard Space Flight Center, NOST, Code 633.2, NASA Goddard Space Flight Center, Greenbelt MD 20771, June 18, 1993.

[5] L. D'Addario. Details of post-pass processing of time correction data, October 15, 1996.

[6] J. Ulvestad. VSOP time correction file conversion specification, Version 1.0, November 30, 1995.

[7] R. Wietfeldt. DSN station generation of SVLBI time correction data, Version 1.0, October 23, 1996.

[8] L. D'Addario. External data interfaces, general requirements. Specification A34300N001, September 20, 1992.

[9] A. Wiercigroch, J. Ulvestad, Y. Murata, and P. Edwards. *VSOP Operational Activities*, March 11, 1996. Section 10 and Section 13.11.